Genetic Algorithms for Mobile and Satellite Telecommunication Systems

George D. Smith
School of Information Systems, University of East Anglia
Norwich, NR4 7TJ. U.K.
Email: gds@sys.uea.ac.uk
www: http://www.sys.uea.ac.uk/People/gds/

1 MOBILE SYSTEMS

By far the most widespread application of EC techniques in the design of mobile telecommunications networks is the assignment of frequencies to base stations. Generally, the network can be viewed as a number of cells, each containing a base station transmitter/receiver. The stages in the design are firstly to locate the base stations based upon geographic and other information, then to determine potential interference between base stations.

For Fixed Channel Assignment (FCA) systems, a further stage is to allocate channels to cells from the available bandwidth, where each cell receives a sufficient number of channels to meet the expected demand and the allocation procedure attempts to minimise interference. For Dynamic Channel Assignment (DCA) systems, the entire pool of channels is potentially available to each cell, and a channel is assigned to a call when it arrives in a cell, or the call is blocked.

There are many approaches to the solutions of the channel assignment problem and [1] provides a good overview of these. Early approaches to the solution of the FCA problem were graph theoretic, based on the relationship between the FCA and graph coloring problems. However, there have been many heuristic techniques applied to FCA. These include neural networks, genetic algorithms, simulated annealing, local search and various greedy and iterative algorithms, to name but a few, see [2].

These heuristic approaches can also be classified as direct or indirect, where a direct approach is one that uses a representation that models which channels are assigned to which cells and an indirect approach is one in which the heuristic solution represents an ordering, either of all the calls or all the cells. Other algorithms are then used to transform the indirect solutions into actual assignments.

A few genetic algorithms employing a direct representation appear in the FCA literature. Papers by Cuppini [3] and Lai and Coghill [4] attempt to solve only reasonably small FCA problems. Ngo & Li [5] successfully apply their GA to more difficult problems but they report run times of over 24 hours for a single run of some of the simple problem instances. In addition they also employ a local search algorithm which fires when the GA gets stuck in local optima. In short, the literature does not provide much evidence that an efficient and scalable channel assignment system could be based on a standard GA.

More recently, however, following on the work done in the EUCLID CALMA project, Ryan et al. [2] have proposed a hybrid GA in which, due to the specialised crossover operator adopted, it is not necessary to completely evaluate a solution each time. The inclusion of domain knowledge in the crossover operator allows partial evaluation, which results in a 90 times speed-up of the algorithm. As a result, Ryan et al. are able to tackle much larger problems [6].

The dynamic channel assignment problem, although essentially attempting to meet the same real-world requirements, is significantly different from its FCA counterpart. Here, each call in any cell is assigned a channel from a pool of channels available to all cells. However, the same electromagnetic compatibility constraints must be satisfied. The main advantage of DCA is that temporary fluctuations in the distribution of calls can be better handled.

The processes involved in DCA are, when a call arrives it is either assigned a channel or it is blocked. The blocking probability can be reduced by reassigning existing calls if this frees up a channel. Also, hand-off algorithms are used to handle the situation of a caller passing from one cell into another.

At the last count, we had accumulated over 120 papers covering different algorithms for these various processes. Only a few, e.g. [7, 8], adopt an EC approach. The reason may be that, to evaluate a potential solution, a discrete event simulation of the network has to be run using distributions to model traffic flow.

The potential for EC in this area is enormous. One approach is to generate a separate permutation of all the channels for each cell. Calls arriving would be assigned in the order generated for that cell. The aim would be to produce a set of permutations to optimise performance over a range of traffic loads.

What can EC offer the mobile systems community? The answer, I believe, lies in the potential of EC to attack the whole problem of network design, not simply the channel assignment/reassignment problems. Thus it is possible that a GA can be used to determine the optimal locations for base stations, as well as the assignment of channels to these stations. To the author's knowledge, this has not been attempted.

2 SATELLITE SYSTEMS

One of the most exciting prospects in global telecommunications is the development of satellite systems, with the launch of the first Iridium satellite in 1997 and around ten other Low Earth Orbit (LEO) systems either in development or operational. These are multi-billion US dollar projects of which the R&D element takes its fair share, due to the complex nature of the problem.

As Gavish points out in his survey [9], the research issues involved in the development of an effective satellite communications system are both diverse and extremely complex, and include:

- the number of orbits and the number of satellites in each orbit,
- the type of orbit (polar, rosette, equatorial or polyhedral) and also the altitude of the orbits,
- the trajectories (circular or elliptic),
- the power management systems,
- the number and type of antennas,
- the routing methodology (ground-based or space-based or hybrid),
- the problem of maintenance and upgrade.

The general aim is to achieve global coverage at a reasonable cost and with a desired level of quality of service.

Whilst it is difficult to ascertain the approaches taken currently by the designers of such systems, due to the sensitive nature of the domain, it is unlikely that heuristic techniques are being utilised to their full potential, especially given their ability to embrace the whole design problem. In my view, the multi-objective, complex optimisation problem posed by the design of a satellite communications system is one on which EC and other heuristic techniques have yet to make a major impact.

References

[1] I. Katzela and M. Naghshineh. Channel assignment schemes for cellular mobile telecommunication systems. *Personal Communications Magazine*, 1996.

[2] M. D. C. Ryan, J. C. W. Debuse, G. D. Smith, and I. M. Whittley. A hybrid genetic algorithm for the fixed channel assignment problem. In *GECCO-99: Proceedings of the Genetic and Evolutionary Computation Conference*. Morgan Kaufmann, 1999.

[3] M. Cuppini. A genetic algorithm for channel assignment problems. *Communication Network*, 5(2):157–166, 1994.

[4] W. K. Lai and G. Coghill. Channel assignment through evolutionary optimization. *IEEE Transactions on Vehicular Technology*, 45(1):91–95, 1996.

[5] C. Y. Ngo and V. O. K. Li. Fixed channel assignment in cellular radio networks using a modified genetic algorithm. *IEEE Transactions on Vehicular Technology*, 47(1):163–172, 1998.

[6] P. Labit. Frequency assignment test problems, 1998. http://www.crt.umontreal.ca/ brigitt/ telecom/test_probs/.

[7] H. G. Sandalidis and P. P. Stavroulakis. A combinatorial evolution strategy for dynamic channel assignment in cellular radio. *ACM Symposium on Applied Computing*, 1998.

[8] H. G. Sandalidis, P. P. Stavroulakis, and J. Rodriguez-Tellez. Combinatorial evolution strategy-based implementation of dynamic channel assignment in cellular communications. *IEE Telecommunications, Conference Proc. No 451*, pages 170–174, 1998.

[9] B. Gavish. Survey of research issues in LEO/MEO based global mobile communication systems. In B. Sanso and P. Soriano, editors, *Telecommunications Network Planning*, pages 219–238. Kluwer, 1999.